Claims

1. An absorption spectroscopy instrument with off-axis cavity alignment, comprising:

an arrangement of two or more mirrors forming an optical cavity, the cavity mirror arrangement defining an axial light path in the resonant cavity wherein each reflection at each mirror thereof occurs at substantially the same spot for said axial light path, the cavity mirror arrangement also defining off-axis light paths in the optical cavity wherein successive reflections at any given mirror thereof occur at different locations for any off-axis light path, the cavity adapted to receive an absorption cell with a sample to be tested;

a light source providing a light beam that is introduced into the optical cavity, the light beam being directed along an off-axis light path in the resonant cavity;

a detector situated in a position to receive and measure a portion of the light beam from the resonant cavity; and

means for processing data representing the light measurement from the detector for analyzing a sample received by said optical cavity.

2. The instrument of claim 1 wherein said optical cavity is a two-mirror cavity.

3. The instrument of claim 1 wherein said optical cavity is a ring cavity.

4. The instrument of claim 1 wherein said optical cavity contains at least one mirror with a spherical reflecting surface curvature.

5. The instrument of claim 1 wherein said optical cavity is arranged to form a stable resonant cavity in which the mirror separation is greater than, or equal to, a confocal cavity arrangement and the mirror separation is less than the sum of the radii of the cavity optics.

6. The instrument of claim 1 wherein said optical cavity contains at least one mirror that has an astigmatic reflecting surface curvature.

7. The instrument of claim 1 wherein said absorption cell is a low-scatter sample gas flow arrangement passing through the off-axis light path of said cavity for measurement of trace chemical species in a gas sample.

8. The instrument of claim 1 further comprising means for modulating the intensity of the light beam introduced from the source into the optical cavity in a manner designed to obtain from the decay rate of the intra-cavity light, a measurement of OA-CR absorption signal by a sample received within the resonant cavity.

9. The instrument of claim 1 further comprising means for modulating the wavelength of the light beam introduced from the source into the optical cavity in a manner designed to obtain from the transmitted light measurement of said detector, a measurement of OA-I absorption signal by a sample received within the resonant cavity.

10. The instrument of claim 1 wherein said light source is any wavelength tunable light source producing a measurable transmitted signal.

11. The instrument of claim 10 wherein the light source is selected from the group consisting of filtered light sources, tunable lasers, and lamps.

12. The instrument of claim 1 wherein the light source is characterized by modulated output power.

13. The instrument of claim 12 wherein the light source is modulated by means of a modulated drive current input.

14. The instrument of claim 1 wherein a direct optical chopping element is situated in the path of the light beam between the light source and the cavity mirror arrangement.

15. The instrument of claim 14 wherein the chopping element is selected from the group consisting of a mechanical chopper, an acousto-optic modulator, an electro-optic modulator.

16. The instrument of claim 1 wherein the detector is positioned to receive light exiting the cavity through one of the mirrors thereof.

17. An absorption spectroscopy instrument with off-axis cavity alignment, comprising:

a stable optical cavity defined by a pair of mirrors with reflectivities of the mirrors being at least 0.5 and with a mirror separation which is greater than or equal to a confocal cavity arrangement and also less than the sum of the radii of curvature of the two mirrors, the pair of mirrors defining an axial light path in the optical cavity wherein each reflection at each mirror thereof occurs at substantially the same spot for said axial light path, the pair of mirrors further defining off-axis light paths in the optical cavity wherein successive reflections at any given mirror thereof occur at different locations for any off-axis light path, the optical cavity adapted to receive a sample to be tested;

a light source providing a light beam that is introduced into the optical cavity, the light beam being directed along an off-axis light path in the optical cavity;

a detector situated in a position to receive and measure a portion of the light beam exiting the optical cavity through one of the mirrors; and

means for processing data representing the light measurement from the detector for analyzing a sample received by said optical cavity.

18. The instrument of claim 17 wherein each mirror has a spherical reflecting surface curvature.

19. The instrument of claim 17 wherein at least one of the mirrors has an astigmatic reflecting surface curvature.

20. The instrument of claim 17 wherein a low-scatter sample gas flow arrangement passes through the off-axis light path of said cavity for measurement of trace chemical species in a gas sample.

21. The instrument of claim 17 further comprising means for modulating the intensity of the light beam introduced from the source into the optical cavity in a manner designed to obtain from the decay rate of the intra-cavity light, a measurement of OA-CR absorption signal by a sample received within the resonant cavity.

22. The instrument of claim 17 further comprising means for modulating the wavelength of the light beam introduced from the source into the optical cavity in a manner designed to obtain from the transmitted light measurement of said detector, a measurement of OA-I absorption signal by a sample received within the resonant cavity.

23. The instrument of claim 17 wherein said light source is any wavelength tunable light source producing a measurable transmitted signal.

24. The instrument of claim 23 wherein the light source is selected from the group consisting of filtered light sources, tunable lasers, and lamps.

25. The instrument of claim 17 wherein the light source is characterized by modulated output power.

26. The instrument of claim 25 wherein the light source is modulated by means of a modulated drive current input.

27. The instrument of claim 17 wherein a direct optical chopping element is situated in the path of the light beam between the light source and the cavity mirror arrangement.

28. The instrument of claim 27 wherein the chopping element is selected from the group consisting of a mechanical chopper, an acousto-optic modulator, an electro-optic modulator.

29. The instrument of claim 17 wherein the detector is positioned to receive light exiting the cavity through one of the mirrors thereof.

30. An absorption spectroscopy method, comprising:

injecting a light beam into an arrangement of mirrors that is arranged to form an optical cavity, the cavity arrangement adapted to receive a sample to be tested, the light beam being introduced into the resonant cavity along an off-axis light path thereof wherein successive reflections at any given mirror of the optical cavity occur at different locations on that mirror;

measuring light from the optical cavity; and

processing light measurement data to obtain an analysis of a sample received by the optical cavity.

31. The method of claim 30 further comprising modulating the intensity of the light beam introduced from the light source into the optical cavity in a manner designed to obtain from the decay rate of the intra-cavity light, a measurement of OA-CR absorption signal by a sample received within the resonant cavity

32. The method of claim 31 wherein the intensity modulation is such that the fall time of the intensity is substantially shorter than the cavity ringdown time, while the repetition cycle time is longer than the ringdown time.

33. The method of claim 31 wherein the intensity is modulated by chopping the light signal produced by the light source.

34. The method of claim 31 wherein the intensity is modulated by controlling the amount of light produced by the source.

35. The method of claim 30 further comprising modulating the wavelength of the light beam introduced from the light source into the optical cavity in a manner designed to obtain from the transmitted light measurement of said detector, a measurement of OA-I absorption signal by a sample received within the resonant cavity.

36. The method of claim 35 wherein the modulating includes dithering the light wavelength about a selected wavelength.

37. The method of claim 30 wherein a low-scatter sample flow configuration directs a flow of sample across the off-axis light path of the laser light beam within the optical cavity.

38. The method of claim 30 wherein the arrangement of mirrors forms a stable optical cavity.

39. The method of claim 38 wherein each of the mirrors has a spherical surface curvature.

40. The method of claim 38 wherein at least one of the mirrors has an astigmatic surface curvature.